



# ***Earth Science Enterprise***

## **Science for Society**

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**ESSAC Meeting**

***November 14, 2002***



***“Accelerating the realization of economic and societal benefits  
from Earth science, information, and technology ...”***



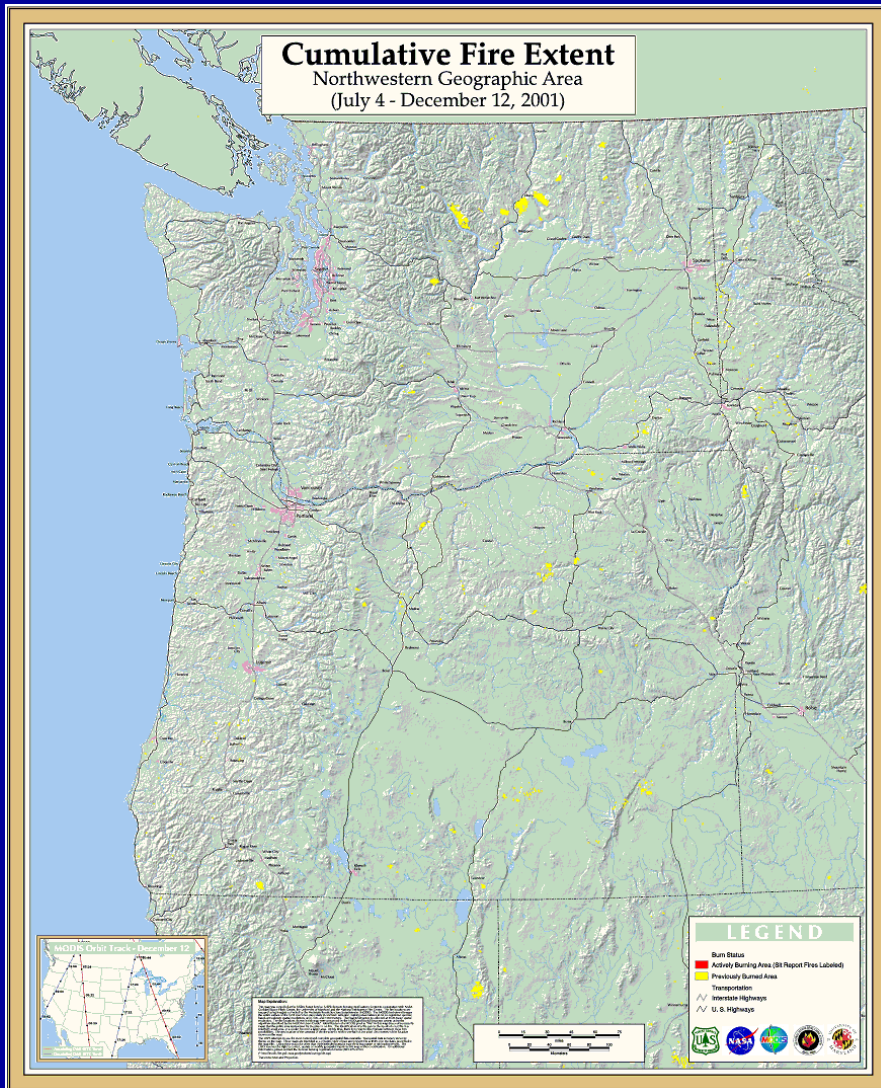
# Earth Science Applications

- FY02 Accomplishments
  - Wildfires, Weather Prediction, Aviation, Data Buy
- NAS Review Findings & Next Steps
  - Endorse strategy, recommend emphasis on partnerships
- Partnerships and Decision Support Systems
  - USDA, NOAA, FAA, USGS, FEMA, DOT, CDC, NIH, EPA, DOE
- SENH – FY02 Applications Projects
  - 10 projects selected
- REASON CAN
  - 175 participants at pre-proposal conference





# Managing Wildfires

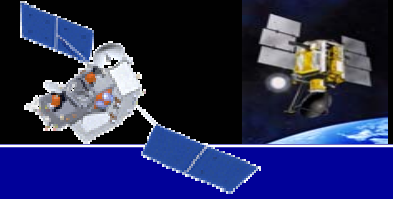


The US Forest Service has established two direct broadcast receiving installations to acquire Terra satellite data, and enable daily, near real-time distribution and decision making on allocation of fire fighting assets.



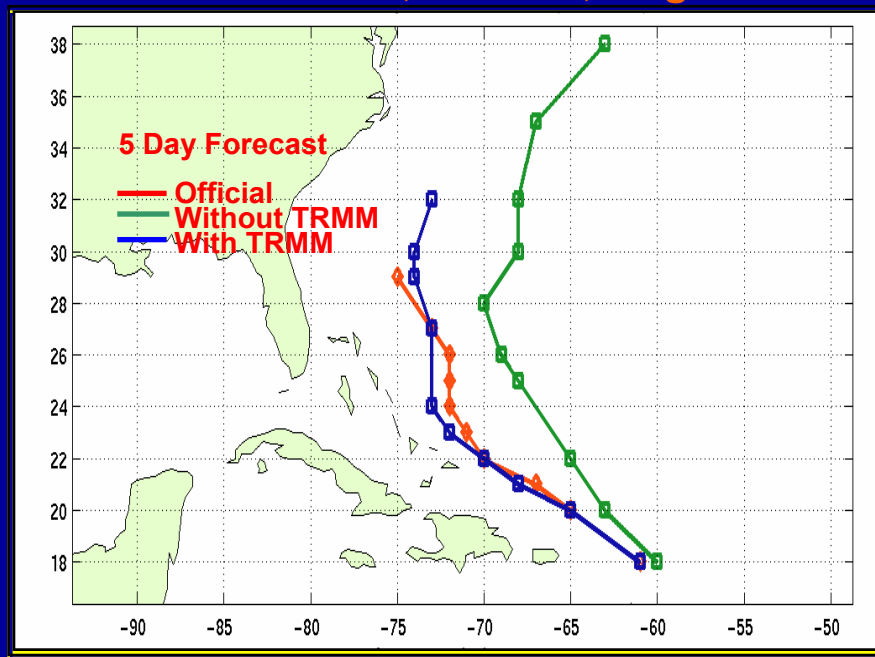


# Improving Hurricane Track Forecasts



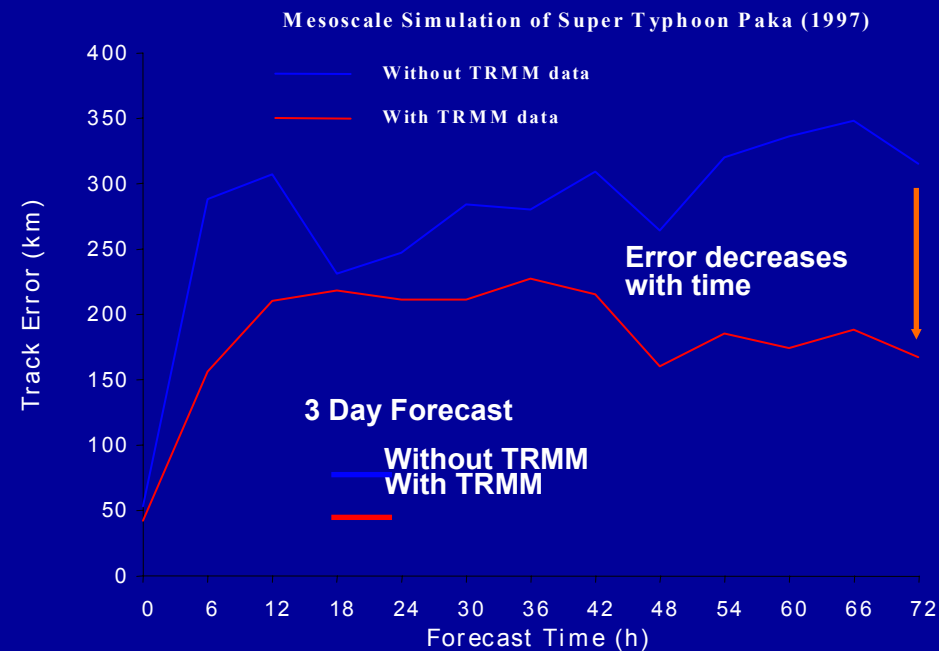
Assimilation of TRMM rainfall location, intensity and vertical structure into hurricane forecast models leads to improvements in forecasts of future position

## Hurricane Bonnie, Atlantic, Aug 1998



Dr. A. Hou, NASA DAO

## Typhoon Paka, Pacific, Dec 1997



Dr. X. Pu, NASA GSFC

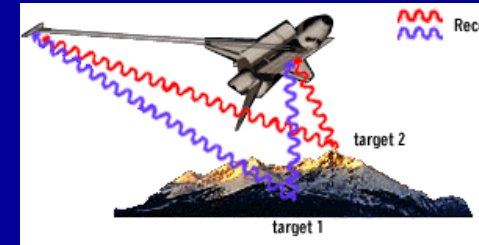
Reduced track errors can save money (\$600,000 per mile of coast evacuated) and save lives by more precise prediction of eye location at landfall



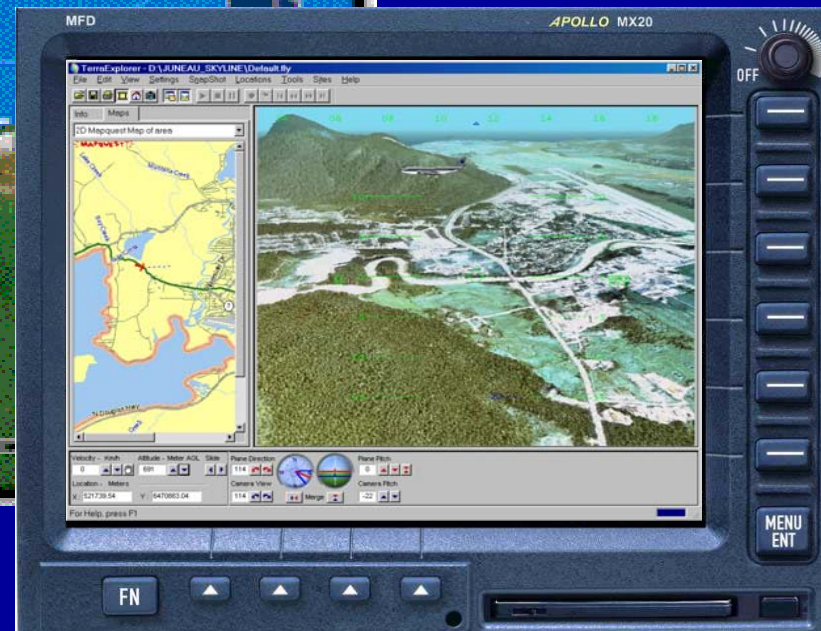




# Benchmarking Guidelines for Aviation



## •Digital Terrain Data





# Purpose (Elevator speech)

- **NASA      Earth Science Enterprise      Applications**
  - conducts research and development of aerospace science and technology
  - to increase knowledge of the Earth system
  - to improve decision support tools to serve society.

**NASA provides systems engineering and scientific research to Earth system science solutions focused on national priorities -- including economic security and homeland security.**





# Approach

- **Focus on national priorities requiring global understanding**
  - finite number of discrete applications
- **Employ “Systems Approach”**
  - missions, models, decision support systems
- **Leverage investments in NASA research and development of missions and models (~\$15B over 10+ years)**
  - as outputs
- **Leverage investments in Federal Agencies and national organizations in decision support tools (on the order of \$1B per year)**
  - existing requirements for inputs
- **Contribute systems engineering resources to assimilate NASA outputs as decision support system inputs**
  - Evaluation, verification and validation, benchmark





# Expectations

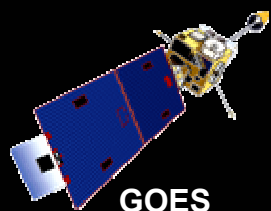
- **Commonly recognized architecture for systems approach – throughout the Earth science community**
- **Strategy that is understood and supported by White House and Congress**
- **Common understanding of program by stakeholders in the 8 (or more) different sectors that have expectations of NASA ESE**
- **Recognized collaboration between/amongst NASA and partner agencies to address advanced solutions based on Earth system science and Earth observations**
- **Improved economic and homeland security manifest through enhanced operational decision support tools serving society**
- **Products/Results – benchmarks for improvements in operational decision support tools**







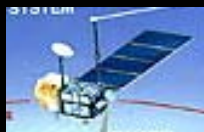
# Constellation: Global Measurements



GOES

TRMM

TOPEX



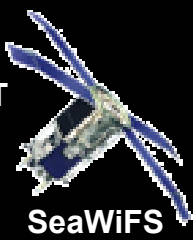
Meteor/  
SAGE



QuikSCAT



Terra



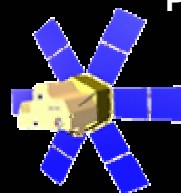
SeaWiFS



Jason



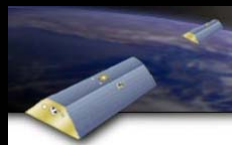
ICESat



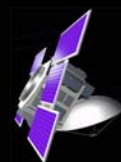
SORCE



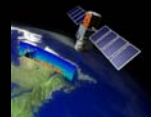
Aura



GRACE



Cloudsat



CALIPSO



GIFTS



Landsat



NOAA/  
POES



Aqua





# Earth System Models: Predication

## LAND



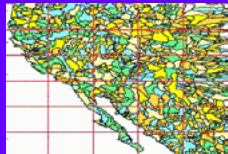
### **GTEC**

*Terrestrial  
Ecosystem Carbon*

**Mosaic** *Energy, water fluxes*  
**CENTURY** *Land change/carbon*  
**VolQuake** *Seismicity*  
**HSPF** *Nutrient transport*  
**ANIMO** *Soil nitrogen cycle*  
**PRMS** *Precipitation run-off*  
**MAESTRO** *Canopy biomass*

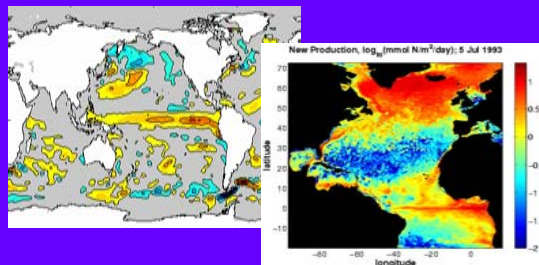
### **Catchment LSM**

*Soil Moisture  
Transport*



## OCEANS/ICE

**ROMS** *Regional circulation*  
**MOM3** *Multi-scale ocean*  
**CSIM4** *Sea-ice*  
**NWW3** *Global/regional waves*  
**BOM** *Coastal & shelf seas*  
**GOTM** *Turbulence & mixing*



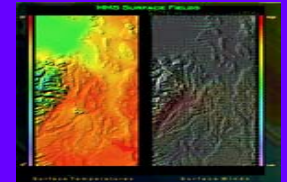
### **Poseidon, HYCOM**

*Ocean GCM*

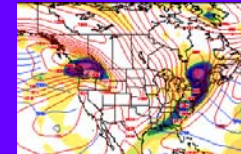
## ATMOSPHERE

### **MM5**

*Mesoscale  
Meteorology*



**CAM/CCM** *Global climate*  
**GISS GCM** *Climate change*  
**BEIS** *Biogenic emissions*  
**MSISE** *Density, temperature*  
**VAFTAD** *Volcanic ash*  
**PRECIS** *Regional climate*



### **Aries/GEOS**

*Atmos. GCM*

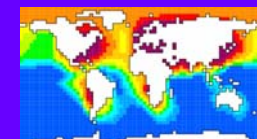
## COUPLED MODELS



### **COUPMODEL**

*Soil-Plant-Atmosphere*

**LOIS** *Land-Ocean*  
**HadCM3** *Ocean-Atmosphere*  
**COLA** *Atmosphere-Land/Biosphere*  
**ZEUS, CCSM** *Land-Ocean-Ice-Atmosphere*



### **AOM**

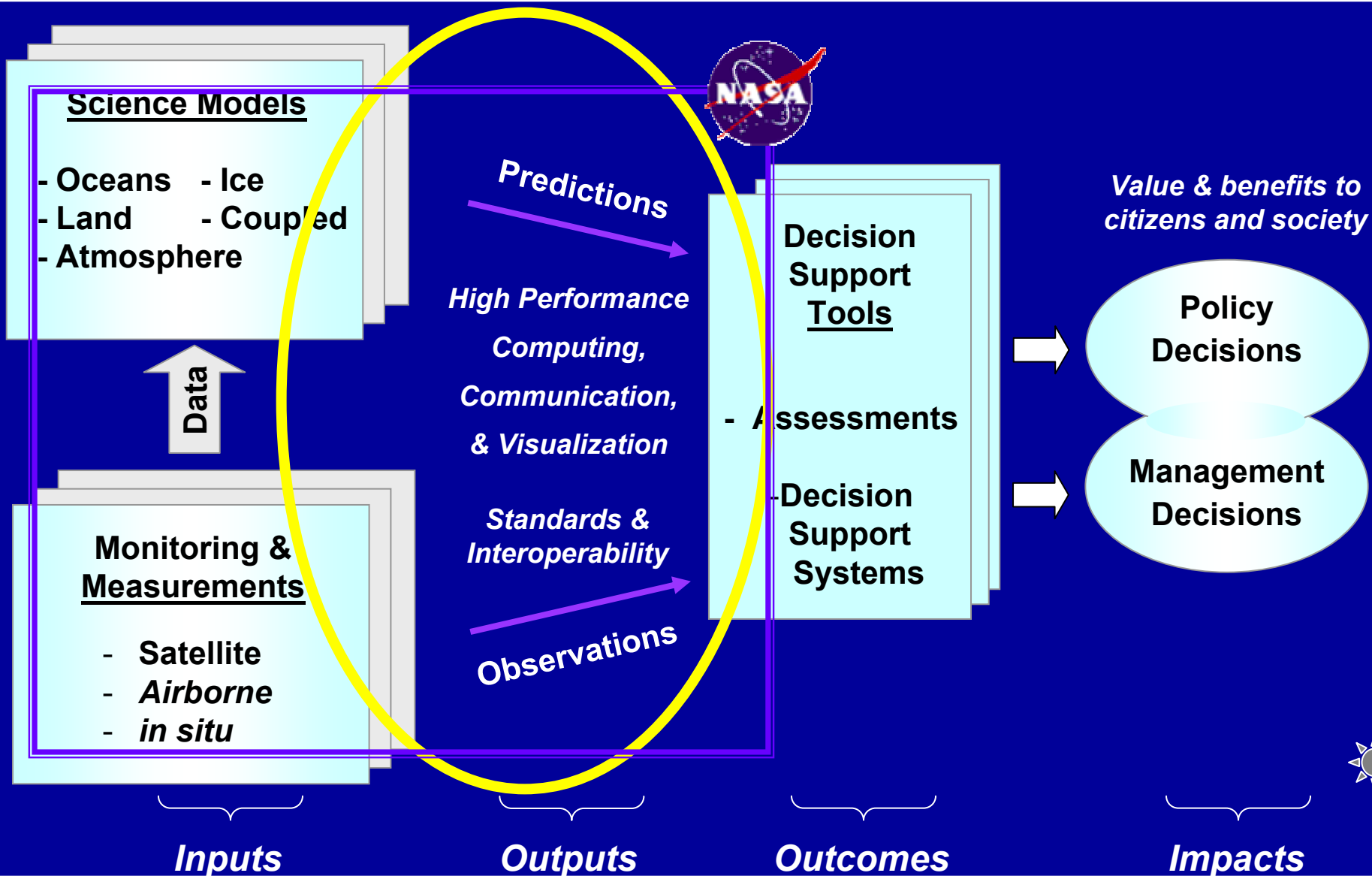
*Atmosphere-Ocean*







# Solutions: Science to Decision Support



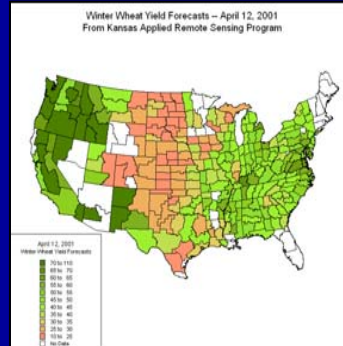




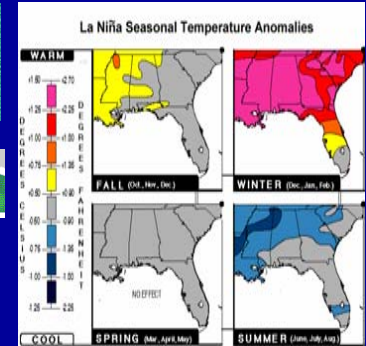
# Decision Support Systems



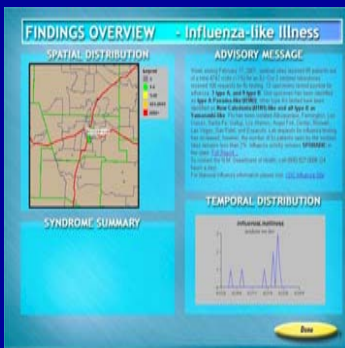
**Aviation Safety:  
National Airspace System**



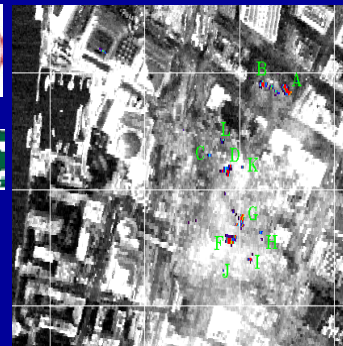
**CCRI:  
Carbon Management System**



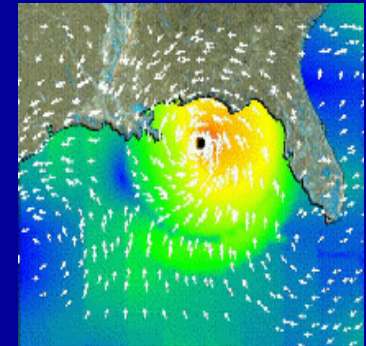
**Energy Forecasting:  
Renewable Energy System**



**Public Health:  
Risk Assessment System**



**Homeland Security:  
Situation Center**

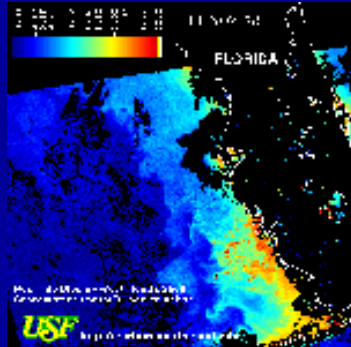


**Disaster Preparedness:  
HAZUS Risk Prediction<sub>3</sub>**

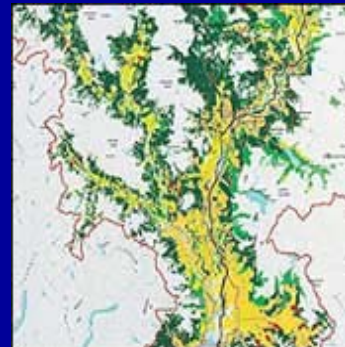




# Decision Support Systems



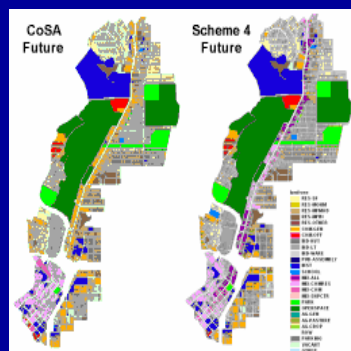
**Coastal Management:**  
**Harmful Algal Bloom Forecast**



**Water Management:**  
**AWARDS, RiverWare**



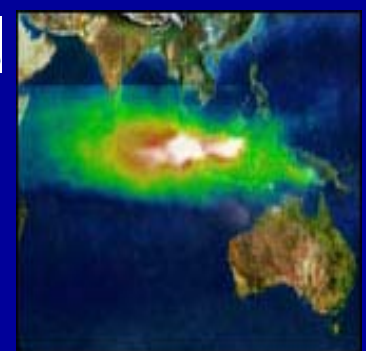
**Invasive Species:**  
**Prediction Center**



**Community Growth:**  
**Urban Dynamics System**



**Agricultural:**  
**Foreign Agriculture Forecast**



**Air Quality:**  
**Community Air Quality**





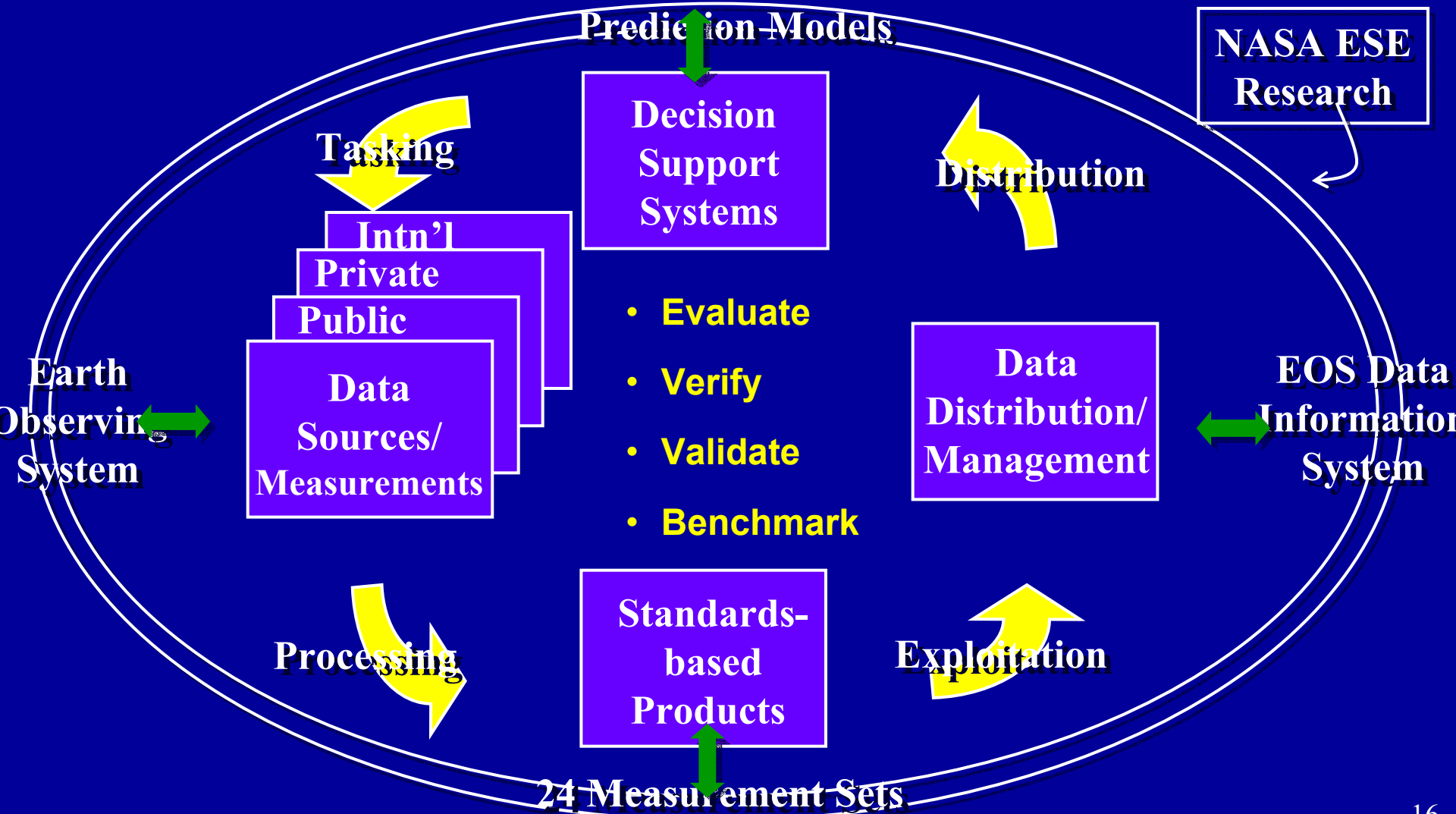


# “One NASA”





# Stennis Space Center – Systems Eng'g







# National Applications



**Carbon  
Management**



**Public Health**



**Energy Forecasting**



**Aviation Safety**



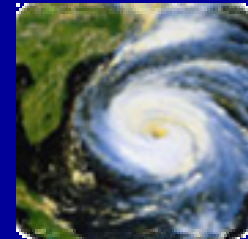
**Water  
Management**



**Homeland  
Security**



**Coastal  
Management**



**Disaster  
Preparedness**



**Agricultural  
Competitiveness**



**Invasive Species**



**Community Growth**



**Air Quality**



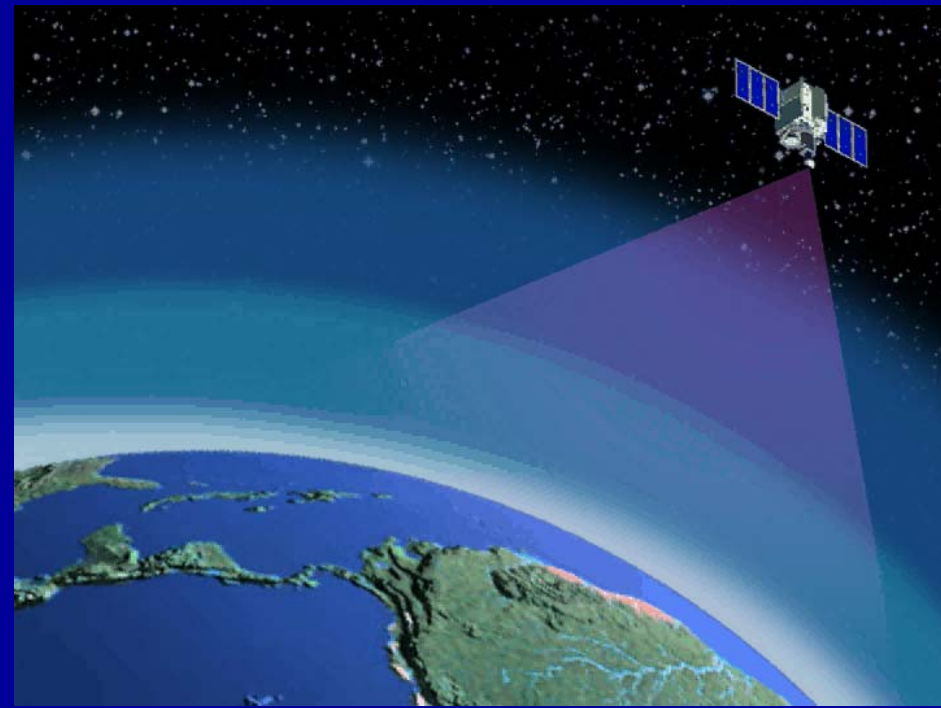


# Aviation: Improving Observations



**180 Balloon Stations  
observe twice daily**

**GIFTS: 1km x 4km  
100,000 obs/minute**



**High-resolution observations are required to accurately  
locate hazardous weather for aviation**



# **Aviation Safety** **Weather Forecasting for Cockpit Visualization**

**\$2B/year**

## Partners:



EOS, NPP, NPOESS & GOES-R

GIFTS – Geosynchronous Fourier Transform Spectrometer Turbulence & Weather Prediction Modeling

Aqua and NPP fly the AIRS and CrIS sensors (Atmospheric Infrared Sounder and Cross-track Infrared Sounder)

NAST (I) Atmospheric Sounder Testbed Infrared (Proteus) Experiments

Advanced Satellite Applications Products (ASAP) Program

**State 1-WX Visualization Systems:** Discrete, Stand-alone weather products, with little satellite sounding data or imagery

**State 1-WX Sensors/Data Sources:** Ground Doppler Radar, 2x daily balloon readings yield 6 to 12-hour forecasts; poor oceanic coverage

High spectral (vertical), horizontal and temporal resolution satellite measurements will render precise numerical weather forecasts and extremely high-resolution wind fields based on the tracking of atmospheric water vapor

Airborne validation of NPOESS instruments provides DSS product development teams with experience at integrating hyperspectral data and information in preparation for subsequent GIFTS and GOES-R missions

Integration of existing GOES imagery and sounding data into AWRP products improve Terminal Convective WX product and Integrated Turbulence Forecast

**NAS-wide Data Link WX Products** provide severe weather location and movement data to controllers and aircrews to promote common situational awareness

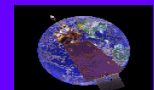
Geostationary satellite technology improvements will vastly improve remote measurement of altitude-resolved vector winds and temperatures, allowing for efficient flight planning, operations and traffic management.

**State 2-WX Visualization Systems:** Fully integrated SVS, WARP & ITWS in-cockpit graphical WX displays featuring real-time weather information with global coverage

**State 2- WX Sensors/Data Sources:** AIRS, CrIS & GIFTS fully integrated into NEXRAD & TDWR systems; prepared for seamless integration of ABS (GOES-R)

**Current trajectory:**  
 Steady improvement in fielding and integration of hyperspectral LEO and GEO satellite data into NWS aviation weather products and AWRP visualization systems, resulting in fully integrated, real-time global aviation WX coverage

Enhanced Aviation Weather DSS and synthetic vision systems that reduce the aviation fatal accident rate by a factor of 10 by 2022



**GOES-L, -M**

2000



**Proteus**

2002



**Aqua**

2004



**NPP/VIIRS**

2006

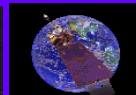


**GIFTS**

2008



**\*NPOESS**



**GOES-R**

2010

**\*Pre-formulation**

2012



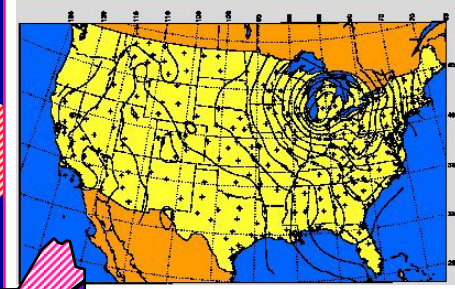


# Disaster Management: Predictions

Thunderstorms and Hail



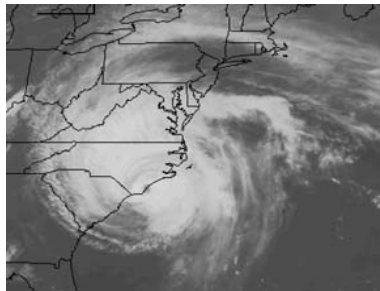
Extratropical Cyclones



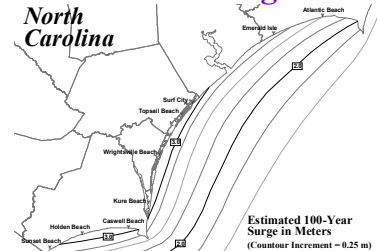
Tornadoes



Hurricanes

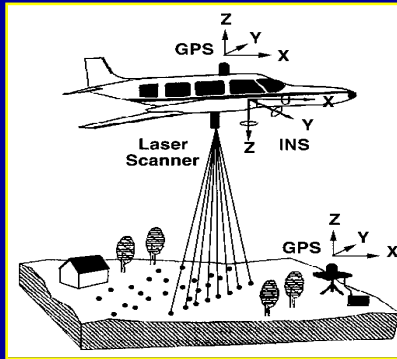


Storm Surge

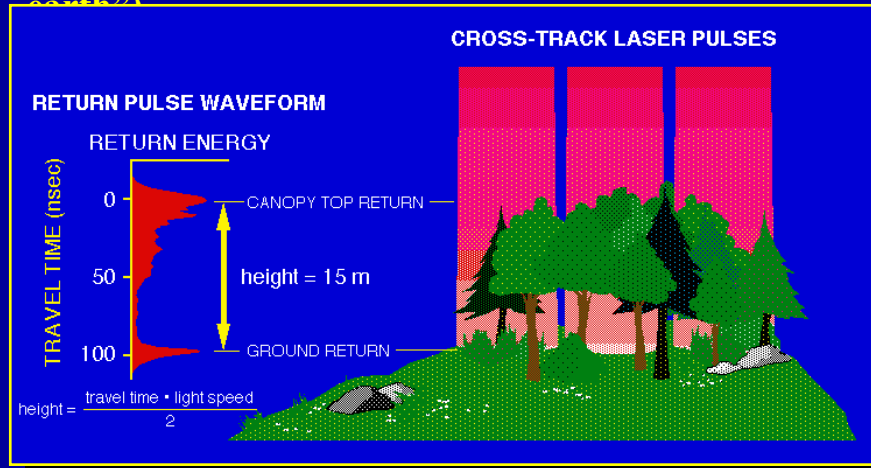




## Light Detection and Ranging (LIDAR)



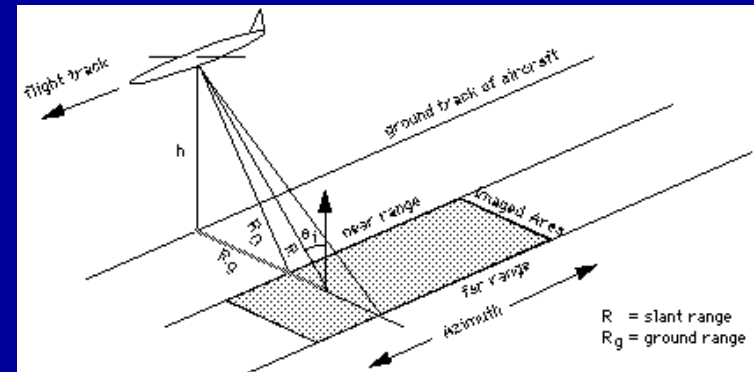
- Potential for high accuracy (10-20 cm range)
- Potential for below- canopy measurements (“bald-canopy?”)



## Interferometric Synthetic Aperture Radar (IFSAR)



- Accuracy levels between 1.5 and 3m over broad flat areas (may ultimately be 0.5 m or lower), but varies over terrain
- Cover larger areas than LIDAR

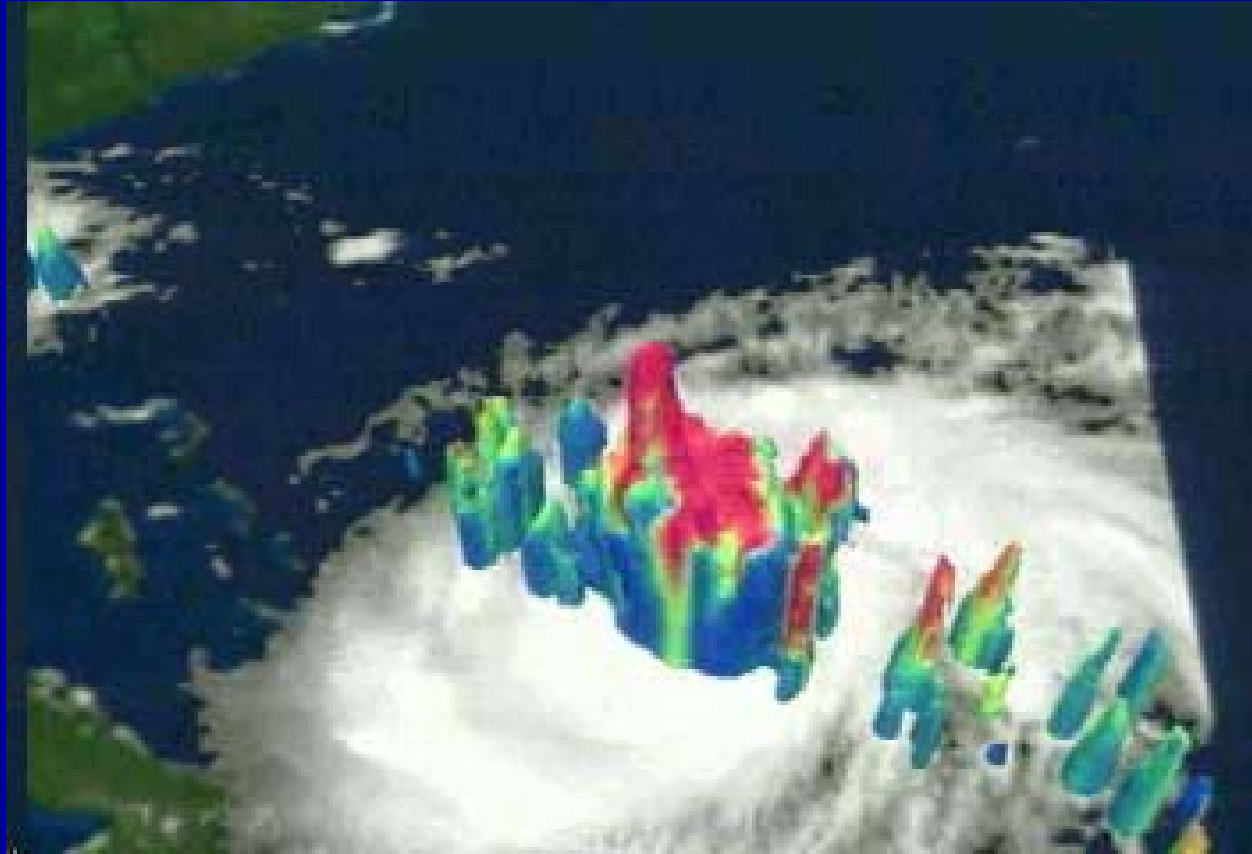




# Disasters: Hurricane Prediction



- Using QuikScat data, forecasters can now predict hazardous weather events over the oceans as much as 12 hours earlier.
- Researchers are developing methods that can detect potential tropical cyclones more than 40 hours earlier than with traditional methods.
- TRMM is providing 3 dimensional maps of precipitation structure.





# Disaster Management: HAZUS - Risk Assessment and Loss Estimation

Date: 6/14/2002

**HAZUS:**  
Earthquakes  
Hurricanes  
Flooding  
Tornadoes



## Primary Partners:



Transfer of advanced event-modeling capabilities using next-generation hardware, software, and communications

**Outcomes:**  
Improvement of FEMA capabilities across all hazards and phases

**Impacts:**  
Reduce losses across all disasters

Provision of real-time weather products for FEMA response applications

**Outcomes:**  
Improvement of FEMA response capabilities

**Impacts:**  
Reduce losses across all weather-driven disasters

Provision of EOS standard products with minimal time delay for FEMA response applications

**Outcomes:**  
Improvement of the HAZUS High Winds Module Final Version

**Impacts:**  
Reduce losses related to hurricane and high wind disasters.

Landsat-7 data for characterization of Forest species type, canopy structure, biomass, and tree height, width, and crown

**Outcomes:**  
Improvement of the HAZUS High Winds Module

**Impacts:**  
Reduce losses related to hurricane and high wind disasters.

FEMA-37 Floodplain Mapping Standard

**Outcomes:**  
Improvement of all US Floodplain Maps feeding the HAZUS Flood Module

**Impacts:**  
Reduce losses related to flood disasters.

**HAZUS:**  
Earthquakes



SeaWiFS



Terra



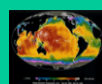
Jason-1



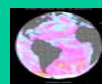
Aqua



SeaWinds



OcnTopo



\* OSWinds



NPOESS

\* Pre-formulation

2000

2002

2004

2006

2008

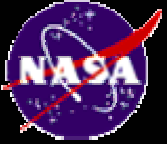
2010

2020

Socioeconomic Impact

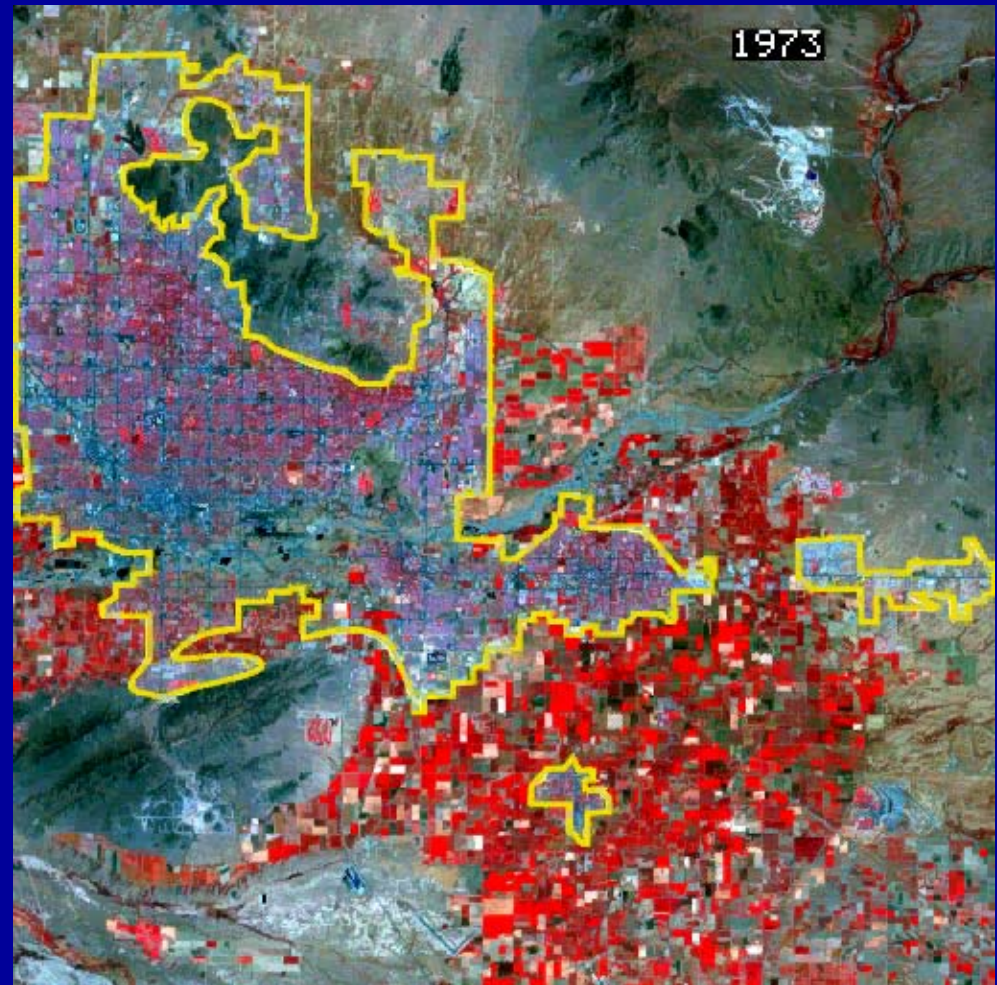
An operational decision support system for quantification and verification of solutions for natural hazard predictions.





# Community Growth: Urban Dynamics

- Transportation Infrastructure
- Urban Growth Planning
- Conservation & Preservation
- Human Impacts on the Land
- Infrastructure and Utilities



Phoenix, AZ





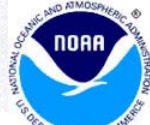


## More timely public information on air quality-related health dangers



- Utilize higher-resolution landcover data
- Improve treatment of surface properties (albedo, moisture)

Outcomes:  
Improved biogenic emissions,  
particularly in urban areas with  
complex surfaces



- Atmospheric models
- Emissions and photochemical models

Outcomes:  
More accurate and more highly-resolved  
temperature and air quality forecasts

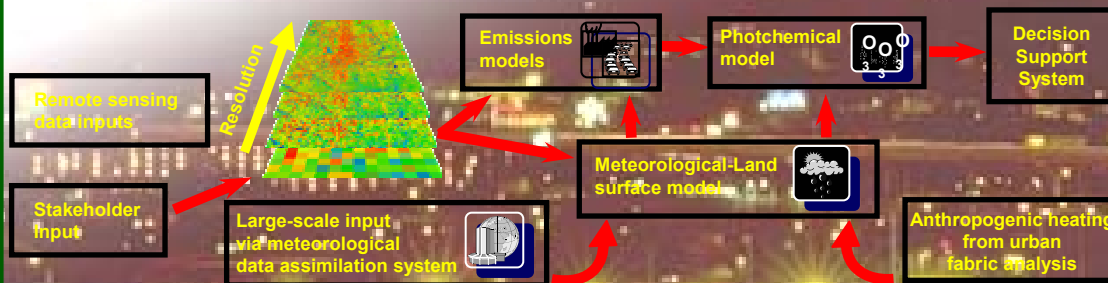


Outcomes:  
More accurate simulation of urban air temperatures and consequently air quality

## Increase stakeholder input into developing solutions for UHI and air quality problems:

Outcomes:  
More realistic assumptions about potential mitigation strategies, better understanding of the role of urban composition in the UHI effect

Outcomes:  
Improved local atmospheric forecasts; improved estimates of emissions and ozone production



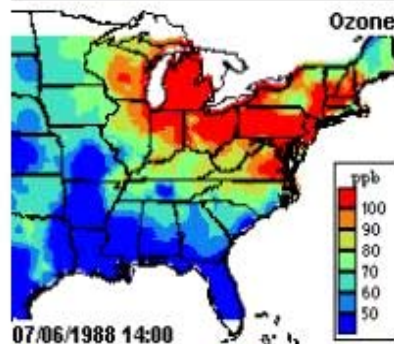
2012

# Operational Decision Support System for enhanced community development, habitability, and sustainability

# Air Quality Assessment

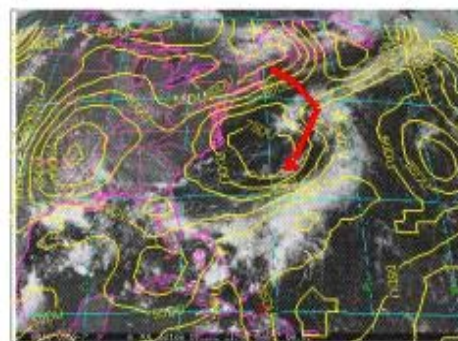
## Satellite Data Captures Northern Pollution Invading Southern States

July 6: Major Northern Pollution Event Established

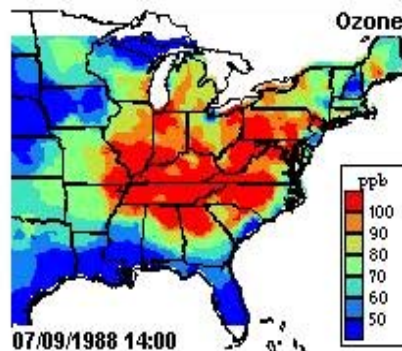


Backward trajectory calculations show air from North contributing to ozone pool

Ozone Builds Off Coast Behind Stationary Front

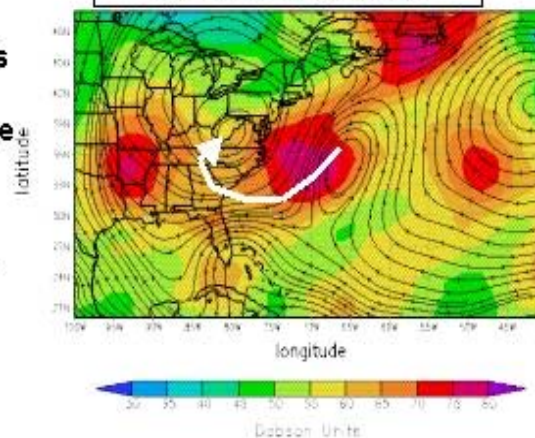


July 9: Pollution Episode Develops In South



Forward trajectories show eastward transport from ozone maximum off the coast of North Carolina into the South 3 days later


Meteorology Conducive to Widespread Stagnation



from Fishman and Balok [1999, *JGR*, 104, pp. 30,319]



# Air Quality Management: Clean Air Standards and Air Quality Forecasts

Earth System Modeling Framework  
Forecasts (c. 2012): 

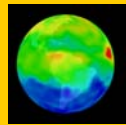
- Robust emissions control planning
- Routine warnings of pollution events
- 3-day air quality forecasts

Prevent 1,000s premature deaths/year  
Mitigate \$5-10 B reduced crop yields

Primary Partners:



- Day/night chemistry/transport
- Trace gas measurements
- Boundary layer resolution



**Outcomes:** Improved pollution forecasts. Improved national emissions control planning/mitigation.

**Impacts:** Mitigate major illnesses and deaths from air pollution episodes.

AURA - TES

- Global/regional/local distribution of ozone
- Tropospheric mixing & B.L. interaction

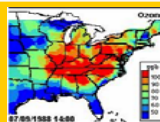


**Outcomes:** Source & destination of long-range dust & pollutants. Route airplanes. Issue health alerts and NAAQS waivers.

**Impacts:** Mitigate wear on airplanes and engines. Improve crop estimates for international markets.

AURA - OMI

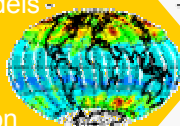
- Ozone profiles/transport
- Build on TOMS & GOME
- Aerosol & trace gas characteristics



**Outcomes:** Assess development policies to achieve or maintain compliance. Improve forecasts of PM and pollution episodes. Warnings to hospitals & farmers.

**Impacts:** Mitigate lung related diseases (asthma, bronchitis, pneumonia). Improve visibility. Benefit crop health & yields.

- Coupled chemistry-aerosol models
- Optical depth data
- Continental inflow/outflow
- Robust satellite data assimilation



**Outcomes:** Quantify contributions of physical & chemical processes to pollutant concentrations. Improve forecasts of ozone and regional transport.


**Impacts:** Accurate, timely forecasts & warnings reduce impaired lung function and use of medications. Reduce hospital admissions and lost work/school days.

- Validations
- Ozone residuals
- Better boundary conditions



**Outcomes:** Assess effects of emission control options. Evaluate development options and emission strategies to set policies and State Implementation Plans (SIP).

**Impacts:** Achievable SIPs permit air quality compliance which reduce development restrictions and improve economic development opportunities within States and Regions.

 **CMAQ Forecasts (c. 2002):**  
State/regional planning.  
Same-day air quality predictions.

**Current trajectory:**  
Steady improvement in chemistry-transport models and pollution episode warnings.



TOMS



GTE



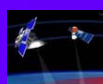
Aqua



AERONET



Aura



CloudSat



CALIPSO



\* Total Column



\*NPOESS

\* Pre-formulation

2000

2002

2004

2006

2008

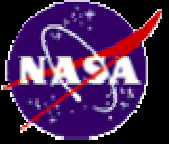
2010

2012

Socioeconomic Impact

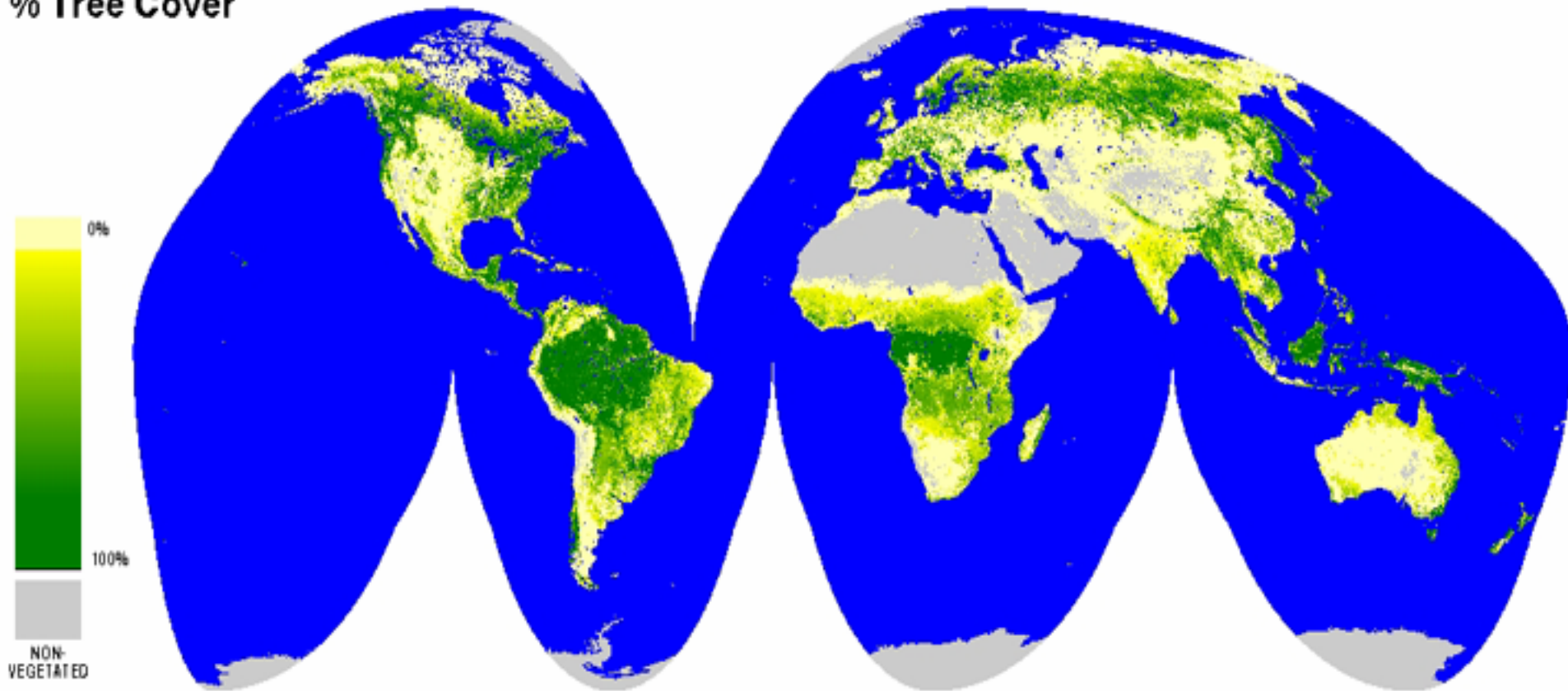
Improved capabilities to air quality management tools to assess, plan and implement emissions control strategies & improve air quality forecasts.





# Carbon Management: Sequestration

% Tree Cover



A prototype data set estimating percent tree cover from 10 to 40 percent based on satellite data acquired by the Advanced Very High Resolution Radiometer in 1992-95. Percent tree cover is likely to be underestimated in areas with significant cloud cover throughout the year. The spatial resolution of 1 km precludes the detection of finer forest fragments. Future satellites with higher spatial resolution will improve detection of forest patches as well as areas undergoing land cover change. Note that this is an equal area map projection and hence tree cover in high latitudes appears less extensive than in conventional maps.

Global Percentage Tree Cover Product derived from AVHRR data

John Townshend / Ruth Defries, University of Maryland

28





# Carbon Management: Toward a Carbon Management Regime

**Carbon Management DSS:**  
Land Sequestration Capacity  
Ocean Sequestration Capacity

Date: 6/14/2002

## Primary Partners:



Socioeconomic Impact

Global Atmospheric CO<sub>2</sub>

Field-level assessment of carbon storage and atmospheric flux

Second-generation global land cover and change products

Capability to assess and predict sink duration (ie. credit longevity) for different land uses

Soil Surface Moisture Measurement\*

Enables modeling of soil carbon storage as a function of soil fertility and vegetative processes

Forest height & canopy volume sampled globally. First global land cover change data product

Capability for volumetric assessment of above ground carbon sinks (3-D vs former 2-D capability) Potential to reduce frequency of costly *in situ* measurements

N. American Carbon Program and related international results incorporated into models (w/ C data assimilation).

Regional monitoring of carbon storage in biomass and soils  
Regional assessment of candidates for carbon sequestration projects

Exploratory studies to extract atmospheric CO<sub>2</sub> from existing satellite sensors; coupled atmospheric-terrestrial model

Assessment of carbon sink strength at continental scale  
Capability to discriminate between land and atmospheric carbon fluxes

EOS & global land cover observations; Carbon data model assimilation

Baseline information and dynamics of terrestrial carbon sources and sinks

**Current trajectory:**  
Steady improvement in model coupling, process characterization, assessment of carbon sources and sinks

**Prototype Carbon DSS**



Landsat 7



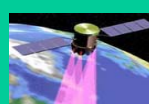
Terra



Aqua



NPP/VIIRS



\*\*VCL



LDCM



NPOESS

\*Pre-formulation  
\*\*In review

An operational decision support system for quantification and verification of terrestrial and oceanic carbon sequestration

2000

2002

2004

2006

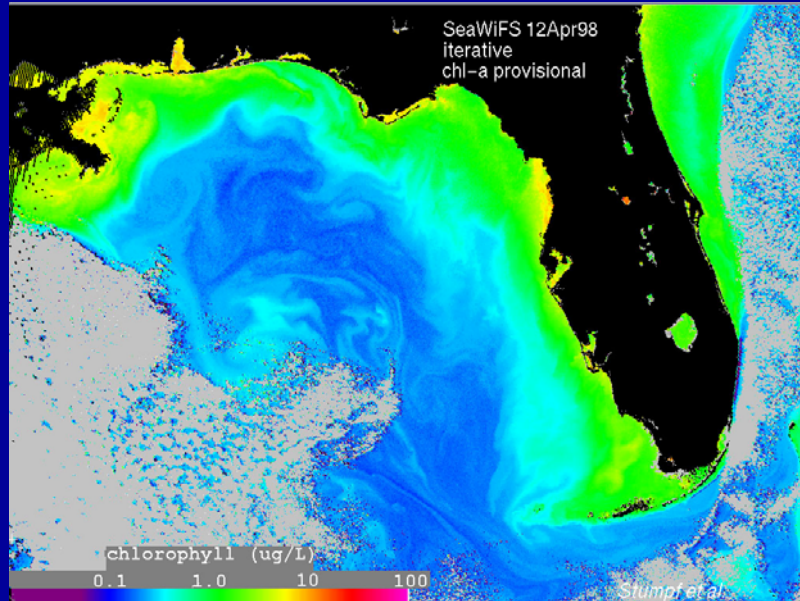
2008

2010

2012

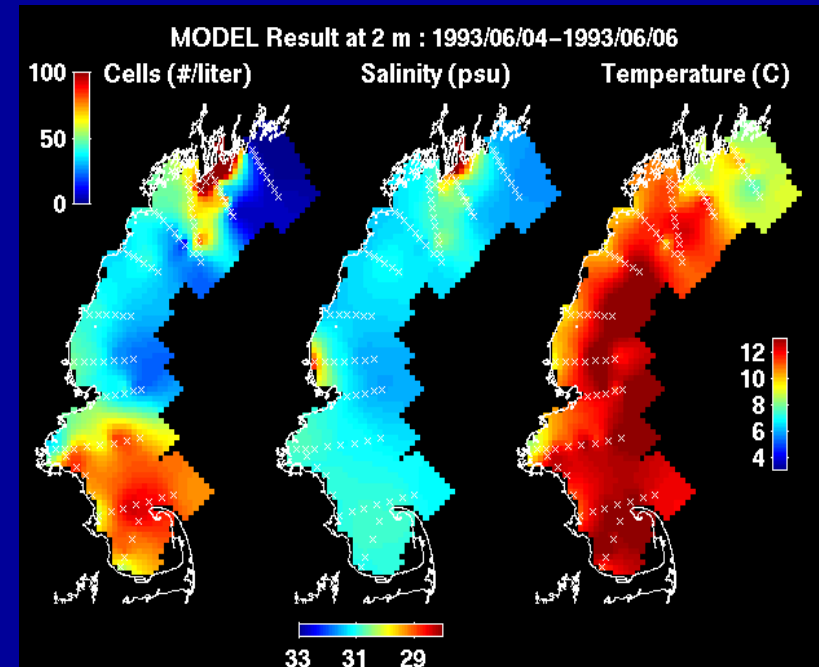


# Coastal Management: Predicting Algal Blooms



## Current Capacity:

Respond to bloom detection with bio-physical models using satellite data and *in situ* sampling to forecast trajectories and impacts



## Future Capacity:

Prediction of bloom onset







# Coastal Management: Harmful Algal Blooms (HAB) & Hypoxia

Date: 6/14/2002

HAB/Hypoxia Forecasts (c. 2012)



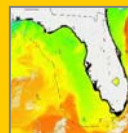
- X-Y day warning
- X% initiation
- Y% landfall +/- X km
- X% dissipation



## Primary Partners:



- Day/night S.S.Temp
- 3-D coastal circulation models incorporating biological data



**Outcomes:** 3-4 day warning of landfall. Routine detection. False negatives less than X%.

**Impacts:** Raise quotas for shellfish harvesting prior to HAB onset.

- Sea surface winds\*
- HAB/phytoplankton speciation



**Outcomes:** Routine identification of particular HAB species. Improved estimates of toxin severity 2-3 day landfall warning.

**Impacts:** Improve design and location of aquaculture facilities.

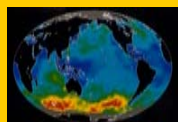
- Bio-optical sensors
- Improved coastal circulation models



**Outcomes:** Predictions of HAB transport, direction, and demise along coasts. Improved estimates of landfall area

**Impacts:** Warnings to fisheries and aquaculture facilities. Reduce impacts to non-target areas.

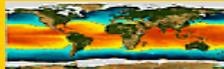
- Improved 2-D ocean circulation models
- Rain rates & salinity
- Sea surface height



**Outcomes:** 1-2 day warning of general landfall. Improved estimates of HAB demise. Warnings to close beaches.

**Impacts:** Reduce public exposure to toxins. Reduce hospital admissions and lost work/school days.

- Ocean color for chlorophyll a
- Sea surface temperatures



**Outcomes:** 0-1 day warning of landfall. Better understanding of HAB speciation. Improved estimates of initiation.

**Impacts:** Reduce economic impacts as possible. Build public confidence in forecasting systems.

HAB/Hypoxia Forecasts (c. 2002)



**Current trajectory:**  
Steady improvement in circulation models, HAB transport, and warning times.



SeaWiFS



Terra



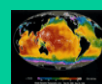
Jason-1



Aqua



SeaWinds



OcnTopo



\* OSWinds



NPOESS

\* Pre-formulation

2000

2002

2004

2006

2008

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2012

Socioeconomic Impact

Improved capabilities to decision support systems to forecast HAB initiation, transport, toxic severity, landfall and demise.

## *Surface Solar Energy Project*

### Objective

To synthesize and convert scientific data to renewable energy industry standards

### History

- NASA Surface Radiation Budget Project develops surface solar insolation data set for solar cooking w/ DOE/NREL
- February 1998, "Development of Surface Solar Energy Data Sets for Commercial Applications for Placement of Solar Power Facilities" proposal funded by NASA
- Meteorological data added (surface temperature, moisture and winds)





# Surface Energy Analysis & Forecasts

Date: 6/14/2002



Global long-term time series of industrial parameters; forecasted weather products for short-term (1-5 day), mid-term (10 day – 90 day) and long-term (1-2 year).

## Primary Partners:



Global Temperature/Moisture information assimilated into forecast and analysis models (GIFTS); improved mid/long-forecasts

DSS improved with short/midterm forecasts; 1<sup>st</sup> long-term forecasts

Cloud Vertical Profile Statistics (CloudSat); Global aerosol distributions (Calipso)

DSS improved with parameter accuracy in time series & short-term forecasts; 1<sup>st</sup> mid-term forecasts.

Improved precipitation products (TRMM, AMSR, SSM/I); Analysis of global precipitation and energy fields; Forecasted parameters (NOAA)

DSS improved with addition of precipitation (biomass-fuel support); 1<sup>st</sup> short-term forecast of industrial parameters

Cloud, aerosol, energy data (Terra/Aqua) to improve/extend time series and evaluate/improve model forecasts; improved reanalysis (GSFC DAO)

DSS improved due to increased accuracy of energy (solar and infrared) and meteorological (temp. humidity, winds, clouds) parameters

Increased resolution and extended time series (SRB and SSE)

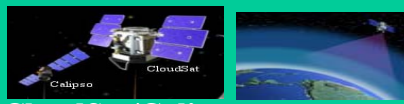
DSS improved with 1<sup>st</sup> 12-year time series data set of industrial parameters with worldwide coverage at 1° x 1° resolution

Surface site climatological mean input data, coarse resolution global data; little weather forecast data

Incremental improvement in weather and climate forecasts from 1-2 day to 1-2 year predictions.



TRMM Terra Aqua



CloudSat/Calipso GIFTS



LDCM



NPOESS

2000

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2008

2010

2012

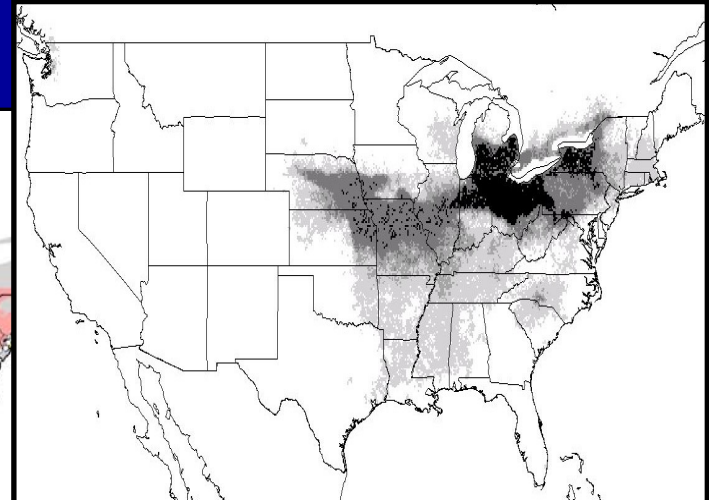
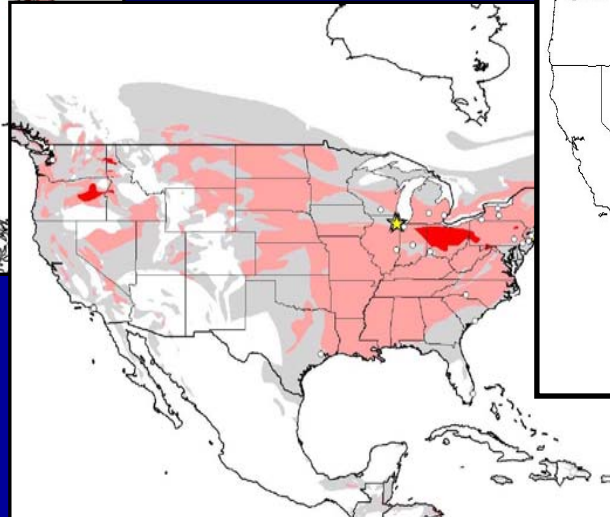
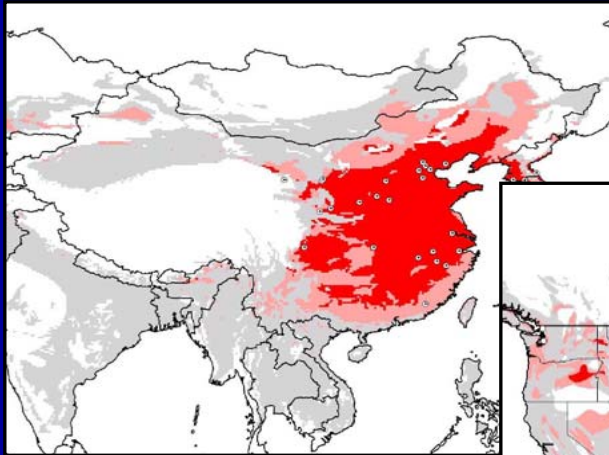
By 2012: Optimization of systems for the development of:

- renewable energy systems (including integration into power grid),
- energy-efficient buildings (construction, renovation, operations),
- biomass crop selection and maintenance strategies, and
- electric power load and supply assessments

Socioeconomic Impact



- Infestations discovered in Asian import warehouses
- Models of climate and habitat control in Asia
- Model climate-based potential North American spread
- Forecast narrowed based on potential habitat





# **Invasive Species: Forecasting and Management of Invasive Species**

Date: 6/14/2002



Center for Biological Invasions:  
Regional, National, Inter'l  
measurements & predictions

## Primary Partners:



Socioeconomic Impact

Global atmospheric CO<sub>2</sub>

Capability to link biotic potential & diversity to carbon storage & flux

Second generation global land cover & change products

Capability to assess & predict patterns of species invasion & biodiversity for different land uses

Soil surface moisture measurements\*

Enables modeling of invasive species spread as a function of soil fertility & vegetative processes

Forest height & canopy volume sampled globally. First global land cover change data product

Capability for assessment of complex structural habitats (3-D vs former 2-D capability)  
Capability for terrestrial & aquatic prediction

N. American Carbon Program & related international results incorporated into models (w/ C, climate, & ecosystem data assimilation).

Continental assessments of native & exotic plant diversity  
Probable locations of rare habitats & potential areas for future invasion

Exploratory studies to map biological resources using existing satellite sensors; coupled atmospheric-terrestrial models

Regional assessments of native & exotic plant diversity  
Capability to discriminate between potential "hot spots" of native & exotic plant diversity

EOS & global land cover observations; Carbon & climate model assimilation

Baseline information & dynamics of major terrestrial types of invasive species

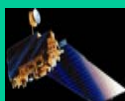
*Current Trajectory*

*Steady improvement in model coupling & enhanced functional, structural, spatial, & temporal environmental measurements*

Center for Biological Invasions:  
Local measurements



Landsat 7



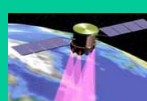
Terra



Aqua



NPP/VIIRS



\*\*VCL



LDCM



NPOESS

\*Pre-formulation  
\*\*In review

An operational National Invasive Species Forecasting System for early detection & monitoring of biological invasions.

2000

2002

2004

2006

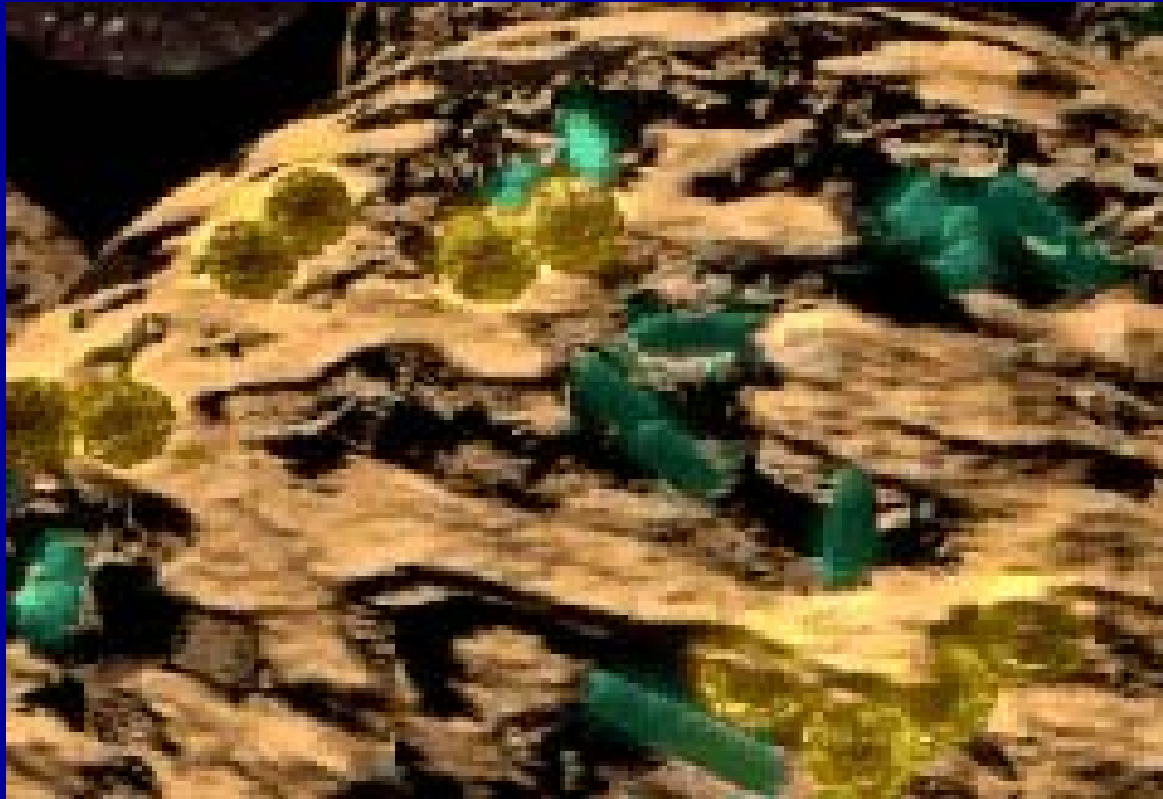
2008

2010

2012



# Public Health: Intercontinental Transport



**Visualization depicting transport of microbes attached to dust particles by transoceanic winds from Africa to North America.**







# Public Health: Infectious disease surveillance systems

Date: 6/14/2002

## Primary Partners:



Data standards, compression algorithms, transmission protocols support sustained integration of geospatial and public health surveillance system data



Public health surveillance systems able to track weather-climate-environmental factors to predict disease outbreaks

Automated disease-specific surveillance enhanced with operational measurements and proven algorithms using weather/climate/environment predictive capacity

High speed computation and technologies developed for integration, analysis, and visualization of weather/climate/environmental data, correlation with adverse public health events.

Weather/climate/environment algorithms supporting disease prediction models are verified, validated, and benchmarked.

Remote sensors yield information on: vegetation/crop type, vegetation green-up, ecotones, deforestation, forest patches, flooded forests, general flooding, permanent water, wetlands, soil moisture, canals, human settlements, urban features, ocean color, sea surface temperature, sea surface height.

Weather/climate/environment-disease relationships discovered, verified, validated and benchmarked for assimilation into operational models (i.e. RSVP)

*This roadmap depicts improvements in surveillance of disease potential coupling environment/disease relationships with development of predictive models. More rapid improvements will occur with integration of geospatial data into existing surveillance systems.*

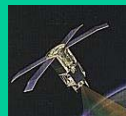
Current disease surveillance approaches lack complete information on weather/climate/environmental factors.



Landsat



Terra



SeaWiFS



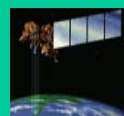
TOPEX



NOAA-POES



Aqua



LDCM



NPOESS

Enhanced public health surveillance systems

- Weather/climate/environment factors accounted for in disease models.
- More accurate and precise disease predictions: warning time increased proportionally

2000

2002

2004

2006

2008

2010

2012

Socioeconomic Impact



- 





# Water Management and Conservation: Assessments and forecasts of water supplies Date: 6/14/2002

AWARDS (c. 2012)

Three forecasts of precipitations and daily crop water use towards reduction of real-irrigation.  
Seasonal forecasts for optimum vegetation selection and improved water use efficiency

## Primary Partners:



Second generation data from missions and prediction and assessment models

Incorporation of NASA's SPoRT project's short-term weather forecasts

Seasonal Forecasts from NASA's Seasonal to Interannual Project (NSIPP)

GRACE & AMSR, combined with GLDAS & LIS projects

Deployment of Land Data Assimilation Systems (LDAS) and Vegetation Data Sets (from MODIS)

USGS  
AWARDS (c. 2002)  
Agricultural Water Resources and Decision Support, limited to real-time rainfall and daily crop water use estimates

Improved capability in DSS resulting from the data, predictions, information products and new science knowledge

Improved capability of DSS to modify advice based on short term predictions (<12 hours) of nominal and severe weather events.

Improved water supply and water use potential for a given area for the DSS to result in improved crop selection .

Improved assessments of surface and sub-surface water storage and transport.

Additional information on current precipitation and potential crop water use statistics. Better knowledge of current crop existence (higher accuracy)

*Current trajectory:  
Steady improvement in water quality and quantity assessments*

**An integrated decision support system assimilating models and measurements of water transport and storage.**



Landsat 7



Terra



Aqua



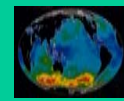
GRACE



\*\*VCL



LDCM



\*GPM



NPOESS

\*In formulation  
\*\*In review

2000      2002      2004      2006      2008      2010      2012

**Socioeconomic Impact**

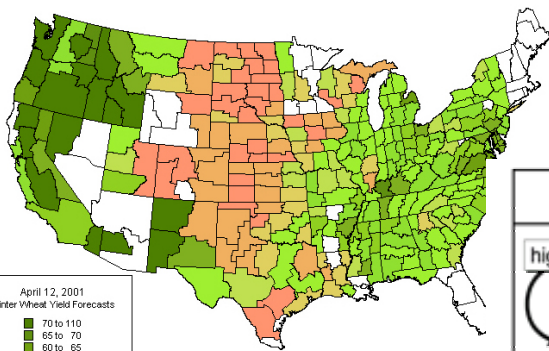




# Agriculture: Improving Efficiency

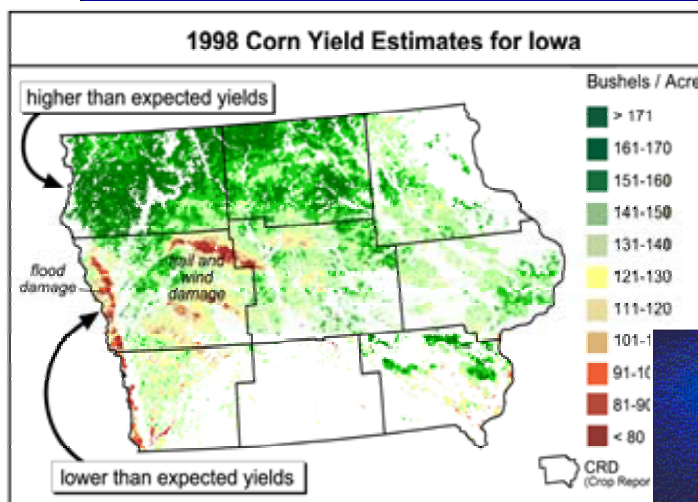


Winter Wheat Yield Forecasts -- April 12, 2001  
From Kansas Applied Remote Sensing Program

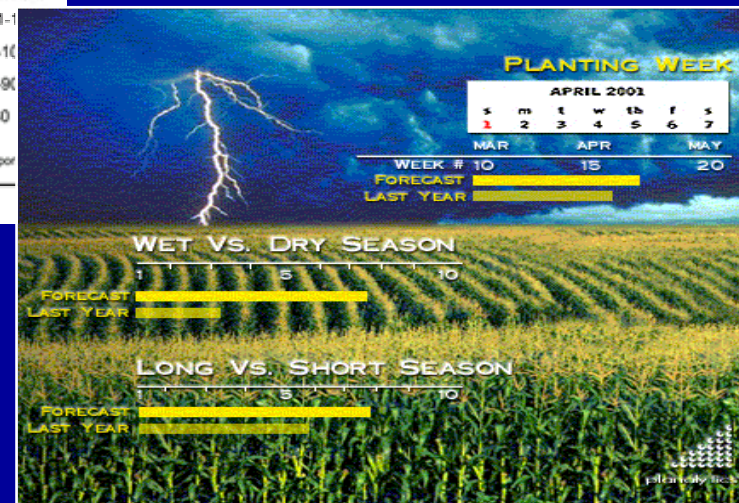


An applications research project with the University of Kansas has led to it's spinning off a new business in crop yield forecasting

1998 Corn Yield Estimates for Iowa



A partnership with USDA and four growers associations representing 100,000 US farmers is demonstrating new techniques for precision agriculture





# ESE for Agricultural Competitiveness

Date: 6/14/2002

NASA

NOAA

Research

Operations

2002-2003

2004-2005

2006-2007

2008-2010

SCIENCE

Snow and Soil  
Moisture Sensing  
Validation  
Experiments

Data Assimilation  
Of Multi-Satellite  
Observations

Weather Forecasting  
Modeling  
&  
Climate Prediction  
Modeling

Meteorology

MISSIONS

TRMM – Tropical  
Rainfall Measuring  
Mission

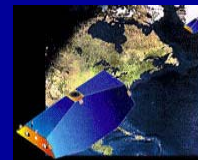
QuikSCAT

Aqua

GRACE – Gravity  
Recovery and  
Climate Experiment

Global  
Precipitation  
Measurement  
(GPM) \*

\* In formulation



Applications  
Research

Validation &  
Verification

Applications  
Demonstration

USDA Competitive Agriculture Program

FAS  
Forecast  
DSS

Soil Moisture  
Products

Precipitation  
Forecasts

Seasonal  
Predictions

New Services &  
Technologies





# Homeland Security: OHS Situation Center Preparation, Warning & Response

Date: 6/14/2002

## OHS Situation Center (c. 2012):

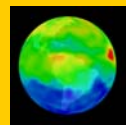
- Prepared with integrated data streams
- Information for warnings & alerts
- Rapid data to support responders and officials with info & analysis



## Primary Partners:



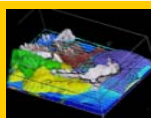
- Day/night air monitoring
- Trace gas measurements
- Improved circulation models



**Outcomes:** Streamline tasking for priority threats and flow of information.

**Impacts:** Reduce major illnesses and deaths from events.

- Long-range deposition
- Bio-optical detection sensors and buoys
- Plume transport visualizations



**Outcomes:** Rapid identification of air/water biological agents. Trace sources & destinations. Issue health alerts.

**Impacts:** Manage public reaction, fear, and over-reaction.

- Plume chemistry and speciation
- Robust satellite data assimilation
- Aerosol & trace gas characteristics



**Outcomes:** Improved information for first responders and recovery efforts. Warnings to food handlers & water treatment plants.

**Impacts:** Reduce exposure to first responders. Minimize extent of economic impacts.

- Plume advection/deposition
- UAV monitoring and rapid response communications links
- Visualization techniques



**Outcomes:** Identify downstream exposure to airborne/waterborne contaminants. Increase warning time to people/officials.

**Impacts:** Reduce health effects and exposure to livestock. Reduce hospital admissions and lost productivity.

- Simulation planning
- Database of sensors
- Sensor validations/verifications



**Outcomes:** Scenario coordination and planning for organized response. Appropriate sensors to match threat.

**Impacts:** Minimize subsequent exposure to populations and secondary effects.

## OHS Situation Center (c. 2002):

Early formation stage.



QuikSCAT



UAVs



Aqua



GRACE



AERONET



Aura



CloudSat



MOBY



GIFTS



NPOESS

\* Pre-formulation

2000

2002

2004

2006

2008

2010

2012

Socioeconomic Impact

Improved capabilities to homeland security officials to prepare, warn, and respond to homeland threats, especially air and water exposure.

*Current trajectory: Improvements in plume modeling, sensor capabilities, and visualizations.*





# Socioeconomic Benefits

<u>National Applications</u>	<u>Estimated Economic Benefits</u>	<u>Citation</u>
<b>Energy Forecasting</b>	<b>\$9.58 B / yr</b> Estimated annual benefit from implementation of the POWER Project (Biomass Energy Industry and Energy Resource Planning Phases only; average for 2002-2017)	<i>LARC Report: An Estimate of NASA/ESE/POWER Program Benefits to the U.S. From 2002 through 2017, June 3, 2002.</i>
<b>Carbon Management</b>	<b>\$150B / yr</b> Cost savings by soil sequestration for meeting the WRE Carbon 550 Emissions constraint as determined by the MiniCAM model	<i>Carbon Sequestration in Soils: Science, Monitoring and Beyond; St. Michaels Workshop, Dec 1998</i>
<b>Agricultural Competitiveness</b>	<b>\$300M / yr</b> Projected annual benefit from improved crop prediction based upon better climate forecasting	<i>NOAA Strategic Plan: A Vision for 2005; September 1998</i>





# Socioeconomic Benefits

<b>Air Quality Management</b>	<p><b>350,000 fewer cases of aggravated asthma &amp; 5,000 premature deaths</b></p> <p><b>1 million fewer cases of reduced lung function in children</b></p> <p><b>\$500 million estimated from ozone reductions...EPA estimate of annual benefit from adopting new NAAQS standards</b></p>	<p>EPA Fact Sheet, June 25, 1997</p> <p>EPA Fact Sheet, July 17, 1997</p> <p>US EPA, National Air Quality and Emissions Trends Report, March 2001</p>
<b>Disaster Management</b>	<p><b>\$240M / yr</b></p> <p>Reduction in losses/yr to the Property and Claims industry through adoption of geospatial technologies estimate \$100M per typical hurricane if 24 hour evacuation predictions could be improved to 300 miles of coastline</p>	<p>Insurance Services Office (ISO), 2002.</p> <p><i>Weather Impacts, Forecasts and Policy</i>, March 2002 BAMS</p>
<b>Public Health</b>	<p><b>\$200M / yr</b></p> <p>Amount that could be reduced to contribute to managing risks for asthma.</p>	<p>Johns Hopkins School of Public Health, May 2000</p>





# Socioeconomic Benefits

Coastal Management	Reduce economic impacts from harmful algal blooms (HABs) affecting 1) public health 2) commercial fishery 3) recreation and tourism 4) monitoring and management costs	WHOA Technical Report 1999
Invasive Species	<b>\$140 to \$408M / yr</b>  Estimated aggregated benefit of reduced environmental damage, reduced crop yield losses and decreased use of herbicides	Office of Technology Assessment (OTA). Report OTA-F-565, 1993.
Water Conservation and Management	<b>\$11B / yr</b>  Approximation of partial benefits of current water quality levels as compared to what they would have been w/o water pollution control programs	Application Profile (U.S. EPA)







# Socioeconomic Benefits

<b>Aviation Safety</b>	<b>\$1.66 B / yr</b>  Average annual savings combined from using synthetic vision system (SVS) to improve airport capacity and delay efficiencies at 10 U.S. airports	NASA Langley Research Center, July 2000
<b>Community Growth</b>	<b>&gt;\$1M / yr for one city</b>  More efficient decision making for planning offices saved one city planning office (Scottsdale, AZ) millions of dollars/yr	GIS World November 1997





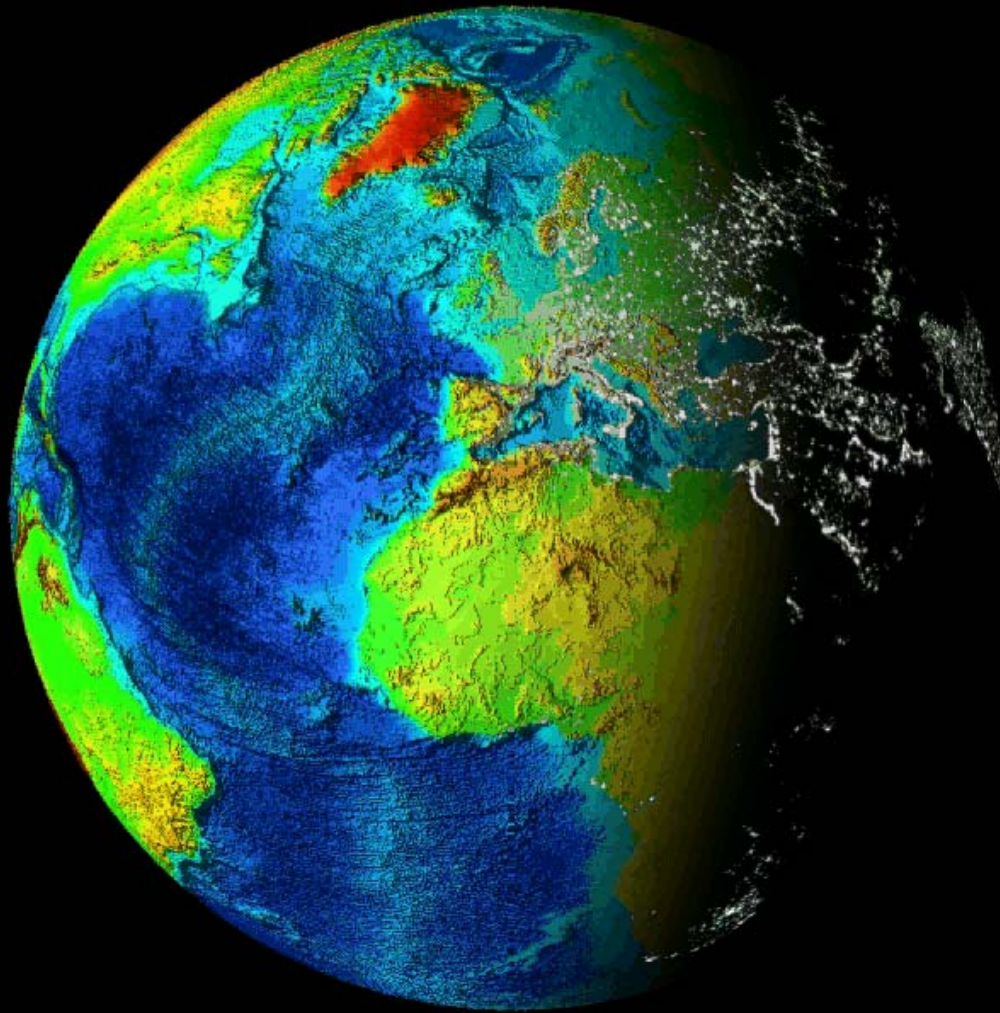
# Community Benefits

- **USGCRP/CCRI**
  - Human Dimensions Working Group
- **NRC Committee Briefings**
  - BESR, BASC, CONNTRO, Geography, Beyond Mapping
- **Research to Operations Community**
  - USWRP, AMS
  - USDA, NOAA, USGS, FEMA, EPA, CDC, OHS, DOT, DOE
- **Outreach**
  - EOM special issue on Earth Science
  - Dedicated issue on Earth Science Models
  - RSE Issue on Federal Government Data Buys





# Education







# Education Program Progress

- **Education Strategy**
  - Purpose, Approach, Expectations
  - Driving Forces
- **GLOBE**
  - Transfer from NOAA to NASA
  - Cooperative Agreement Notice
  - 100 International Partners
- **Virtual Earth: A World of Science and Solutions**
- **DEVELOP**





# Driving Forces

- Agency vision and mission
  - “inspire...”
  - “...as only NASA can”
- Code N focus
  - K-12, Mission Specialist, Telepresence
- Findings of Revolution Workshop for Earth Science
- Success with product developments
- Success with Grants
- Limited adoption in classrooms on national scale





# Enriching Earth Science Education

- Provide the Nation with life-long learning opportunities about climate change research, weather prediction, and solid Earth and natural hazards
- Partner with educators to build human capacity to create effective decision support resources



*Improving public awareness, appreciation and understanding of Earth system science and encouraging pursuit of careers in science and technology using NASA-unique content and resources*







# Virtual Earth: Science and Solutions



**Models**



**Education**



**Decision Support**



**Measurements**





# Learning through Telepresence

## 4-D Internet Visualization



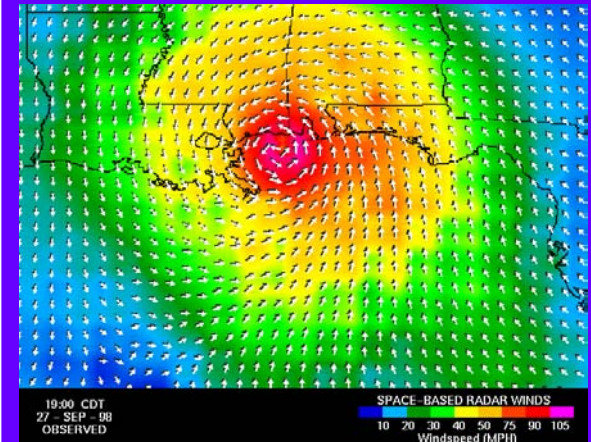
Access to continuously updated databases of Earth science data with capability to view time series

## Context-Sensitive Education Modules



Access to continuously updated education modules on Earth science, remote sensing technologies, missions, models, and decision support tools

## Context-Sensitive Models & Decision Support Tools



Access to continuously updated models and decision support tools for learning how to run scenarios

